The Use of Hip Positions to Predict Bilateral Force Asymmetries in NCAA Athletes with ACL Injuries

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Introduction

Among college athletes in the National Collegiate Athletic Association (NCAA), one of the most common critical injuries sustained is the anterior cruciate ligament (ACL) injury (Kay, Register-Mihalik, Gray, Djoko, Dompier, & Kerr, 2017). Additionally, reinjury either to the contralateral or ipsilateral ACL occurs between 6-29% of all individuals who undergo ACL reconstruction (Hughes, Musco, Caine, & Howe, 2020). Furthermore, after an ACL injury, individuals are more likely to develop osteoarthritis in the knee (Myklebust & Bahr, 2005). Previous studies have found that kinetic asymmetries, including vertical ground reaction force, knee and ankle flexion moments, etc., may be a result of loading more weight onto the uninjured limb to protect the injured limb. These asymmetries may be a risk factor for future ACL injuries (Sharafoddin-Shirazi, Letafatkar, Hogg, & Saatchian, 2020).

Squatting is a popular exercise in strength training for individuals in rehabilitation for ACL reconstruction as it is generally considered a safe and functional movement. Additionally, it has shown that during a double-stance parallel squat, individuals who have received ACL reconstruction surgery do not load their injured and non-injured legs equally, putting more weight on the uninjured leg and resulting in kinetic asymmetries (Beynnon, Johnson, Felimng, stankewich, & Renström, 1997). However, the force plates necessary to test for asymmetries in ground reaction forces may not be available to clinicians in a rehabilitation setting working with athletes who have had ACL reconstruction surgery. Therefore, a method of detecting kinetic asymmetries with minimal, inexpensive equipment is necessary to ensure that athletes are not released from rehabilitation before kinetic asymmetries in the lower limbs are minimized. It has

not yet been researched whether or not a relationship exists between medial-lateral movements and kinetic asymmetries in post-operative ACL reconstruction patients. By examining these movements while monitoring kinetic asymmetries during a squatting task, a relationship can be determined.

The purpose of this study was to determine whether a relationship between medial-lateral hip and shoulder movements and kinetic asymmetries existed in NCAA athletes who had undergone ACL reconstruction. It was hypothesized that there would be a quantifiable relationship between medial-lateral hip and/or shoulder movements and ground reaction force in a squatting task in NCAA athletes who had undergone ACL reconstruction surgery.

Methods

Subjects in this research consisted of NCAA collegiate athletes who had suffered an ACL injury within six months of initial testing. There were both right and left ACL injuries included in the study, and some subjects had previous ACL injuries in addition to the injury studied. The subjects initially recruited included three female soccer players, a female cheerleader, two female basketball players, one female volleyball player, one male basketball player, seven male football players, and three male wrestlers. The mechanisms of the ACL injuries included eight that were non-contact, five that were indirect contact, four that were direct contact, and one that was unidentified. Additionally, 7 of the subjects had previous ACL injuries. Subjects were first tested within 6 months (T1) of ACL reconstruction and again between 6-12 months (T2). Fifteen of the subjects participated in the study, and twelve completed both of the T1 and T2 assessments. Subjects were first tested within 6th months (T1) of ACL reconstruction and again between 6-12 months (T2). The mean age of the subjects when they injured their ACL was 20.03±1.29 years

old. The mean length of time between ACL reconstruction surgery and T1 and T2 were 3.11 ± 0.84 months (ranging from 1.87 to 4.53 months) and 8.84 ± 1.25 (ranging from 6.87 to 11.36 months), respectively. The mean height of the subjects was 1.80 ± 0.12 m, while the mean mass was 82.28 ± 20.14 kg. The research was approved by the University of Wyoming's Institutional Review Board and every subject signed an informed consent form.

For the data collection, subjects changed into spandex and running shoes (Ghost 5; Brooks Sports, Bothell, WA, US). Then, the anthropometric data of each subject was recorded, as well as the date of ACL injury, the date each subject received ACL reconstruction surgery, the date each subject returned to play, as well as any previous ACL injuries, if any, the subject sustained in the past. Subjects performed a warm-up of their choosing and were then fitted with retroreflective markers. The markers were placed on the left and right acromioclavicular joints, greater trochanters, anterior mid-thighs, medial and lateral femoral condyles, tibial tuberosities, inferior anterior shanks, medial and lateral malleolus, both calcanei, first toes, and fifth metatarsal heads.

Figure 1. Placement of the retroreflective markers.

Subjects then performed three double-leg squats with each foot on its own force plate (4060-10; Bertec, Columbus, OH, USA). The squats were also recorded using eight infrared cameras that recorded three-dimensional footage of the retroreflective markers. (Bonita 10, Vicon Motion Systems Ltd, Oxford, UK). The cameras recorded at a sampling frequency of 160 hertz, while the force plates recorded at a sampling frequency of 1600 hertz. For the motion of the squat itself, subjects were instructed to keep feet shoulder-width apart, hold their hands parallel to the ground, and squat as deeply as they could.

Figure 2. A posterior view of the squat movement, including the standing position as well as the deepest part of the squat.

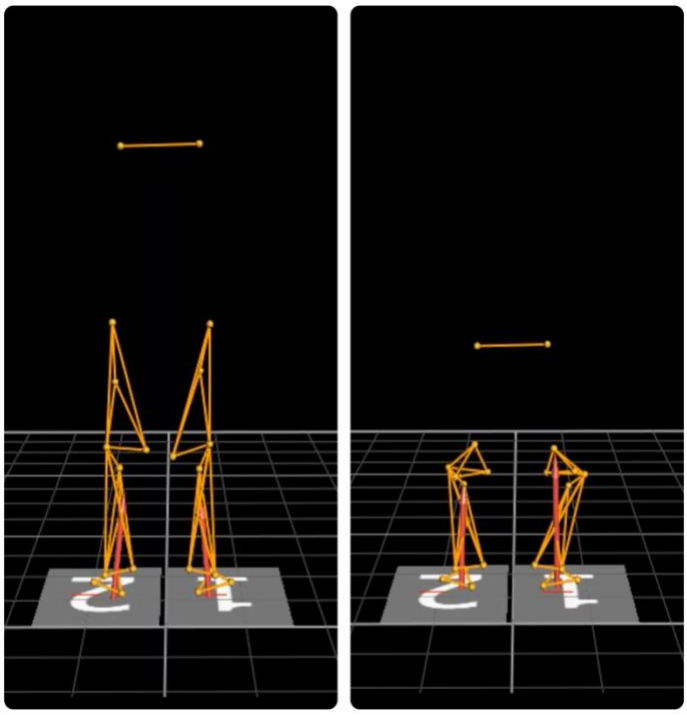

Figure 3. A posterior view of the retroreflective markers of the squat movement, including the standing position as well as the deepest part of the squat.

After the data was collected, the three-dimensional marker data were filtered, and the area in the space of the acromioclavicular joints and greater trochanters was characterized as the trunk reference. Weight-shifting and lateral bending were characterized using the retroreflective markers. The sagittal joint angles of the hip and knee were calculated as well as the angles between the trunk and thigh and the angles between the thigh and shank reference frames. The vertical ground reaction force on each limb was collected from the force plates and normalized to each subjects' weight.

The asymmetry index (AI) of the knee moment as well as the bilateral force was calculated using the following formula:

(non-injured leg – injured leg) / the larger value among the two legs

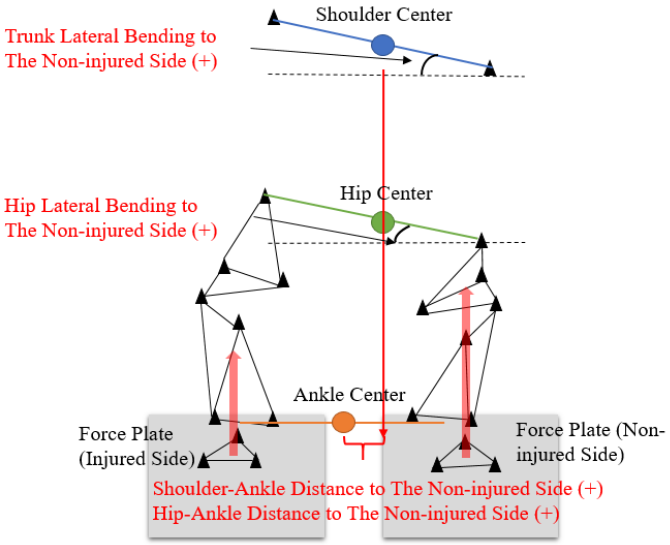

Figure 4. Dependent variables of the squat viewed posteriorly.

The data used for these calculations was from the lowest position of the squat. Sample t-tests were performed on the uninjured and injured limbs and for both T1 and T2 asymmetry indices. This quantified any changes in bilateral asymmetries in the year following ACL reconstruction for the subjects. In order to find associations between the medial-lateral shoulder and hip movements and kinetic asymmetries, simple linear regressions were performed on the kinetic and kinematic asymmetry indices data. Statistical significance for a type-1 error rate was set at 0.05. IBM SPSS Statistics 22 software (IBM Corporation, Armonk, NY, USA) was used for all statistical analyses.

Results

At T1 and T2, the asymmetry indices of knee extension moment were able to be predicted by the hip position asymmetry indices (T1: $R^2 = 0.72$, $p < 0.01$; T2: $R^2 = 0.40$, $p = 0.01$).

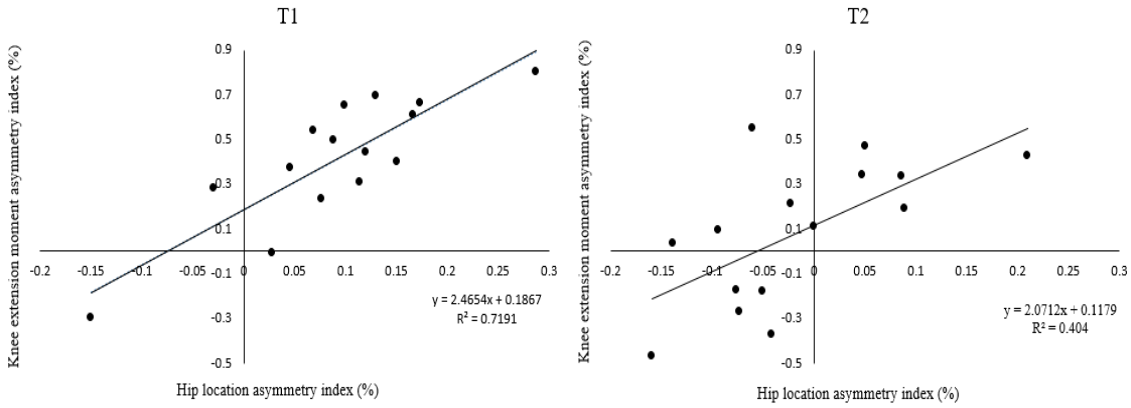

Figure 5. The correlation of knee extension moment asymmetry indices and hip location asymmetry indices among NCAA collegiate athletes during a squatting task.

The hip (T1: $R^2=0.73$, $p<0.01$; T2: $R^2=0.53$, $p<0.01$) position AIs at T1 and T2 were strongly associated with vertical ground reaction force and therefore vertical ground reaction forces can be used to predict hip movement. It was found that, during the trunk and weight-shifting, the body's center of mass moved closer to the non-injured limb in order to unload force on the injured limb.

Discussion

The results of this study show that since both vertical ground reaction force and hip positions are associated with weight-shifting to unload the injured leg during a squat, hip

position movement of the injured side suggesting weight-shifting to the uninjured leg is indicative of bilateral vertical ground reaction force asymmetries in the lower limbs. These results are also consistent with the findings of Beynnon et al. (1997), who found that individuals who have undergone ACL reconstruction surgery load more weight on their uninjured leg, resulting in kinetic asymmetries during a double-leg parallel squat (1997). This means that, in rehab settings, force plates will not be necessary to measure bilateral force asymmetries on the lower limbs, which has been found to increase the risk of reinjury to the athlete (Sharafoddin-Shirazi et al., 2020). Instead, clinicians may only have to record their ACL patients doing a double-leg squat in the frontal plane and review the footage to watch for the hip of the injured side shifting to the uninjured side, as this change in hip position and weight-shifting implies that there may be force asymmetries. If force asymmetries are present, rehabilitation can continue until the asymmetries are minimized so the athlete can safely return to play with a lowered risk of reinjury.

A manuscript of this study is currently being written under Dr. Boyi Dai at the University of Wyoming to be submitted to a journal for publication. I will be listed as a co-author on the article.

References

Beynnon, B. D., Johnson, R. J., Fleming, B. C., Stankewich, C. J., Renström, P. A., & Nichols, C. E. (1997). The Strain Behavior of the Anterior Cruciate Ligament During Squatting and Active Flexion-Extension. *The American Journal of Sports Medicine*, *25*(6), 823–829. https://doi.org/10.1177/036354659702500616

Hughes, G., Musco, P., Caine, S., & Howe, L. (2020). Lower limb asymmetry after anterior cruciate ligament reconstruction in adolescent athletes: A systematic review and meta-analysis. *Journal of Athletic Training, 55*(8), 811-825. https://doi.org/10.4085/1062-6050-0244-19

Kay, M. C., Register-Mihalik, J. K., Gray, A. D., Djoko, A., Dompier, T. P., & Kerr, Z. Y. (2017). The Epidemiology of Severe Injuries Sustained by National Collegiate Athletic Association Student-Athletes, 2009–2010 Through 2014–2015. *Journal of Athletic Training*, *52*(2), 117–128. https://doi.org/10.4085/1062-6050-52.1.01

Myklebust, G., & Bahr, R. (2005). Return to play guidelines after anterior cruciate ligament surgery. *British Journal of Sports Medicine, 39*(3), 127–131. https://doi.org/10.1136/bjsm.2004.010900

Sharafoddin-Shirazi, F., Letafatkar, A., Hogg, J., & Saatchian, V. (2020). Biomechanical asymmetries persist after ACL reconstruction: results of a 2-year study. *Journal of Experimental Orthopaedics*, *7*(1). https://doi.org/10.1186/s40634-020-00301-2